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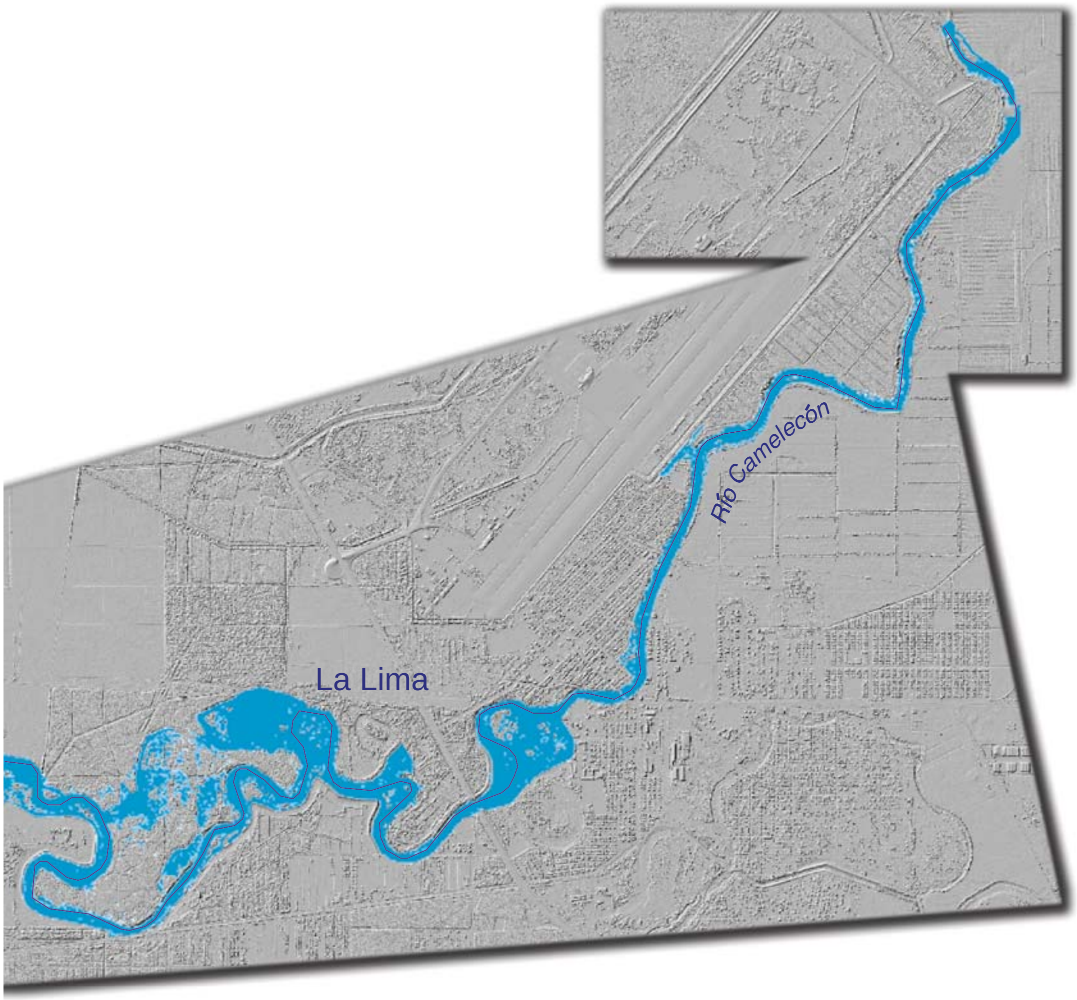
Flood-Inundation Maps for La Lima, Honduras

U.S. Geological Survey Open-File Report 02-255



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U.S. Department of the Interior
U.S. Geological Survey

Fifty-Year Flood-Inundation Maps for La Lima, Honduras

By Mark C. Mastin and Theresa D. Olsen

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 02-255

Prepared in cooperation with the
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

Tacoma, Washington
2002

U.S. DEPARTMENT OF THE INTERIOR
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Building 810
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Denver, CO 80225-0286

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CONVERSION FACTORS

Multiply	By	To obtain
cubic meter per second (m^3/s)	35.31	cubic foot per second
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
millimeter (mm)	0.03937	inch
square kilometer (km^2)	0.3861	square mile

VERTICAL DATUM

Elevation: In this report "elevation" refers to the height, in meters, above the ellipsoid defined by the World Geodetic System of 1984 (WGS 84).

Fifty-Year Flood-Inundation Maps for La Lima, Honduras

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ABSTRACT

After the devastating floods caused by Hurricane Mitch in 1998, maps of the areas and depths of the 50-year-flood inundation at 15 municipalities in Honduras were prepared as a tool for agencies involved in reconstruction and planning. This report, which is one in a series of 15, presents maps of areas in the municipality of La Lima that would be inundated by Río Chamelecón with a discharge of 500 cubic meters per second, the approximate capacity of the river channel through the city of La Lima. The 50-year flood (2,400 cubic meters per second), the original design flow to be mapped, would inundate the entire area surveyed for this municipality. Because water-surface elevations of the 50-year flood could not be mapped properly without substantially expanding the area of the survey, the available data were used instead to estimate the channel capacity of Río Chamelecón in La Lima by trial-and-error runs of different flows in a numerical model and to estimate the increase in height of levees needed to contain flows of 1,000 and 2,400 cubic meters per second. Geographic Information System (GIS) coverages of the flood inundation are available on a computer in the municipality of La Lima as part of the Municipal GIS project and on the Internet at the Flood Hazard Mapping Web page (http://mitchnts1.cr.usgs.gov/projects/floodhazard.html). These coverages allow users to view the flood inundation in much more detail than is possible using the maps in this report.

Water-surface elevations for various discharges on Río Chamelecón at La Lima were determined using HEC-RAS, a one-dimensional, steady-flow, step-backwater computer program. The channel and floodplain cross sections used in HEC-RAS were developed from an airborne light-detection-and-ranging (LIDAR) topographic survey of the area and ground surveys at three bridges. Top-of-levee or top-of-channel-bank elevations and locations at the cross sections were critical to estimating the channel capacity of Río Chamelecón. These elevations and locations are provided along with the water-surface elevations for the 500-cubic-meter-per-second flow of Río Chamelecón. Also, water-surface elevations of the 1,000 and 2,400 cubic-meter-per-second flows are provided, assuming that the existing levees are raised to contained the flows.

INTRODUCTION

In late October 1998, Hurricane Mitch struck the mainland of Honduras, triggering destructive landslides, flooding, and other associated disasters that overwhelmed the country's resources and ability to quickly rebuild itself. The hurricane produced more than 450 millimeters (mm) of rain in 24 hours in parts of Honduras and caused significant flooding along most rivers in the country. A hurricane of this intensity is a rare event, and Hurricane Mitch is listed as the most deadly hurricane in the Western Hemisphere since the "Great Hurricane" of 1780. However, other destructive hurricanes have hit Honduras in recent history. For example, Hurricane Fifi hit Honduras in September 1974, causing 8,000 deaths (Rappaport and Fernandez-Partagas, 1997).

As part of a relief effort in Central America, the U.S. Agency for International Development (USAID), with help from the U.S. Geological Survey (USGS), developed a program to aid Central America in rebuilding itself. A top priority identified by USAID was the need for reliable flood-hazard maps in Honduras to help plan the rebuilding of housing and infrastructure. The Water Resources Division of the USGS in Washington State, in coordination with the International Water Resources Branch of the USGS, was given the task to develop flood-hazard maps for 15 municipalities in Honduras: Catacamas, Choloma, Choluteca, Comayagua, El Progreso, Juticalpa, La Ceiba, La Lima, Nacaome, Olanchito, Santa Rosa de Aguán, Siguatepeque, Sonaguera, Tegucigalpa, and Tocoa. This report presents and describes the determination of the area and depth of inundation in the municipality of La Lima that would be caused by a discharge of 500 cubic meter per second (m^3/s) in Río Chamelecón.

The original intent of the study was to delineate the area that could be inundated by the 50-year-flood discharge. The 50-year flood is one that has a 2-percent chance of being equaled or exceeded in any one year and on average would be equaled or exceeded once every 50 years. The 50-year flood was estimated to be 2,400 m^3/s from a regression equation that relates the 50-year-flood discharge with drainage basin area and mean annual precipitation (Mastin, 2002). The drainage area of Río Chamelecón at La Lima was determined to be 3,757 square kilometers (km^2) using a geographic information system (GIS) program to analyze a digital elevation model (DEM) with a 93-meter cell resolution from the U.S. National Imagery and Mapping Agency (David Stewart, USGS, written commun., 1999). The mean annual precipitation over the Río Chamelecón drainage basin was determined to be 1,568 mm using a GIS program to analyze a digitized map of mean annual precipitation at a scale of 1:2,500,000 (Morales-Canales, 1997-1998, p. 15). For comparison, the flood due to Hurricane Mitch was estimated by a three-section, slope-area indirect method to be 4,700 m^3/s upstream at Río Chamelecón near El Tablón, which drains 2,670 square kilometers (Mark Smith, U.S. Geological Survey, written commun., 2001). The Hurricane Mitch flood on the Río Chamelecón combined with floodwaters of the Río Ulua to completely inundate the town of La Lima and much of the Sula Valley.

It soon became apparent that the 50-year-flood discharge would overwhelm the capacity of the channel and inundate the entire area that was surveyed for La Lima. The full extent of the flooding could not be determined from the limited survey that was made; therefore, without knowing the topography of the full extent of the flooded area, accurate estimations of the water-surface levels for the 50-year flood could not be determined from the numeric model. Consequently, the data that were available were used to estimate the discharge-carrying capacity of the existing river channel in the city of La Lima and to estimate the additional height needed for existing levees to contain flood discharges of 1,000 and 2,400 m^3/s. The discharge of 1,000 m^3/s was determined to be the approximate capacity of the highway bridge and the road bridge at the city center.

Purpose, Scope, and Methods

This report provides (1) results of the hydraulic analysis to estimate the water-surface elevations of the channel-capacity flow of Río Chamelecón within the urban area of La Lima at cross sections along the stream profile, (2) locations and elevations of top-of-levee or top-of-river-banks at cross-sections, (3) water-surface elevations of the bridge capacity and 50-year flood discharges assuming that the flows are contained within the main channel, and (4) channel-capacity inundation maps for a discharge of 500 m^3/s for Río Chamelecón at La Lima, showing area and depth of inundation.

The analytical methods used to calculate the water-surface elevations and to create the flood-inundation maps are described in a companion report by Mastin (2002). Water-surface elevations along Río Chamelecón were calculated using HEC-RAS, a one-dimensional, steady-flow, step-backwater computer model, and maps of the area and depths of inundation were generated from the water-surface elevations and topographic information.

The channel and floodplain cross sections used in HEC-RAS were developed from an airborne light-detection-and-ranging (LIDAR) topographic survey of La Lima and ground surveys of three bridges. Because of the high cost of obtaining the LIDAR data, the extent of mapping was limited to areas of high population where flooding is expected to cause the worst damage. The findings in this report are based on the condition of the river channel and floodplains on March 6, 2000, when the LIDAR data were collected, and on January 13, 2001, and on March 21, 2001, when the bridges were surveyed.

Acknowledgments

We acknowledge USAID for funding this project; Jeff Phillips of the USGS for providing data and field support while we were in-country; Roger Bendeck, a Honduran interpreter, for being an indispensable guide, translator, and instrument man during our field trips; and Humberto Calderon from the Comision Ejecutiva Valle de Sula, who gave us important local insights into the hydrology of Río Chamelecón.

DESCRIPTION OF STUDY AREA

Río Chamelecón flows from the west, and then, as it approaches the urban area of La Lima, turns to the northeast to flow through to the center of the city and beyond. The study area includes the main channel and floodplains of Río Chamelecón from approximately 4 km upstream of the main highway bridge just southwest of La Lima to approximately 6 km downstream of the bridges at the center of La Lima (figure 1). The river lies in the large, flat Valle de Sula, which it shares with Río Ulua, a larger river. During major flooding, such as the flooding during Hurricane Mitch, the two rivers combine and inundate most of the valley as one river. The headwaters of Río Chamelecón are located to the west and south in the Sierra Espiritu Santo along the Guatemalan border.

The river is fairly flat and meandering, with an average slope of 0.0006. Meander scars in the floodplain are common in the upstream reaches of the study area. The streambed material ranges from sand and gravel to cobbles in the main channel in the area of the bridges--the only area closely observed. Outside of the urbanized area, agriculture (shown primarily as banana plantations on figure 1) is the predominate land use on the overbank areas. Earthen levees were observed on both banks of the river upstream and downstream of the highway bridge, a sandbag levee was observed on the left bank (looking downstream) under the bridges in town, and a vertical wall levee was observed on the right bank near the bridges in town. Various discontinuous levees were visible on a shaded-relief computer image of the topographic survey data. The bankfull elevation of the channel is above the land surface on the landward side of the levees or channel banks in much of the area, and as a result, the town and surrounding area are susceptible to extensive flooding once the channel capacity is exceeded.

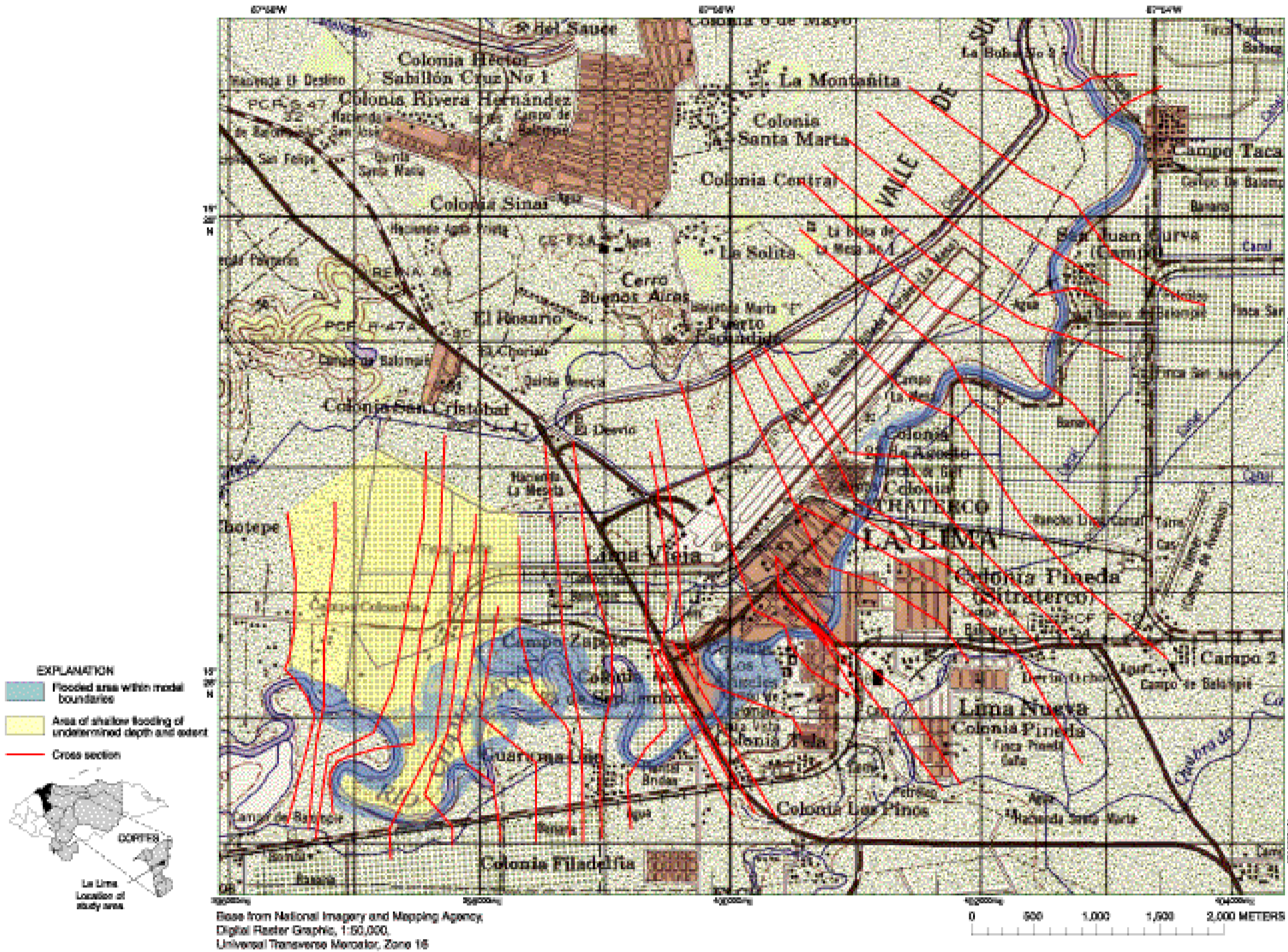

Figure 1. Location of study area and cross sections, and the area of inundation for a dicharge of 500 cubic meters per second on Río Chamelecón at La Lima, Honduras.

WATER-SURFACE PROFILES

Once a design flood discharge has been chosen, a profile of water-surface elevations along the course of the river can be estimated with a step-backwater model, and later used to generate the flood-inundation maps. The U.S. Army Corps of Engineers HEC-RAS modeling system was used for step-backwater modeling. HEC-RAS is a one-dimensional, steady-flow model for computing water-surface profiles in open channels, through bridge openings, and over roads. The basic required input to the model are stream discharge, cross sections (geometry) of the river channels and floodplains perpendicular to the direction of flow, bridge geometry, Manning's roughness coefficients (*n* values) for each cross section, and boundary conditions (U.S. Army Corps of Engineers, 1998).

Cross-section geometry was obtained from a high-resolution DEM created from a LIDAR survey and ground surveys at three bridges. The LIDAR survey was conducted by personnel from the University of Texas. A fixed-wing aircraft with the LIDAR instrumentation and a precise global positioning system (GPS) flew over the study area on March 6, 2000. The relative accuracy of the LIDAR data was determined by comparing LIDAR elevations with GPS ground-surveyed elevations at 1,185 points in the La Lima study area. The mean difference between the two sets of elevations is 0.125 meter, and the standard deviation of the differences is 0.092 meter. The LIDAR data were filtered to remove vegetation while retaining the buildings to create a "bare earth" elevation representation of the floodplain. The LIDAR data were processed into a GIS (Arc/Info™) GRID raster coverage of elevations at a 1.5-meter cell resolution. The coverage was then processed into a triangular irregular network (TIN) GIS coverage. Cross sections of elevation data oriented across the floodplain perpendicular to flow direction (figure 1) were obtained from the TIN using HEC-GeoRAS, a pre- and post-processing GIS program designed for HEC-RAS (U.S. Army Corps of Engineers, 2000). The underwater portions of the cross sections cannot be seen by the LIDAR system. However, because the LIDAR surveys were conducted during a period of low flows, the underwater portions were assumed to be insignificant in comparison with the cross-sectional areas of flow at channel capacity; therefore, they were not included in the model except at the Highway bridge where field surveys included the underwater portion.

The LIDAR vegetation filtration process used to create a bare-earth representation failed to remove the crops shown as grids of dots on figure 1. Comparing actual bare earth areas next to areas in crop production showed differences on the order of 2 meters. Since most of the analysis was confined to non-agricultural areas between the river banks or levees, this did not affect the outcome for most of the area. However, there is extensive overbank flow on the left bank upstream of the highway bridge between cross sections 12.290 and 15.272 (figure 2). The high elevations believed to be the top of the agricultural crops on the left overbank portion of these cross sections were removed, leaving the lowest elevations, which are believe to be a better representation of the bare earth.

A field-survey visit to the study area on March 21, 2000, noted four bridges in the study area; the twin bridges (considered one bridge in the hydraulic model) on the divided highway heading northwest to San Pedro Sula and southeast towards El Progreso, a footbridge and road bridge near the center of La Lima, and a railroad bridge about 1 km farther downstream. The railroad bridge was situated well above the water, with abutments shoreward of the channel banks. The bridge appeared not to obstruct or constrict high flows; therefore, it was not field-surveyed or included in the hydraulic model. The other three bridges were field surveyed and the bridge geometry was included in the model.

Levees in the hydraulic model were positioned on the cross sections at constructed levees near the channel bank as seen in the LIDAR images, or in the absence of a levee, at the top of the channel bank. The elevations of the top of levees or banks were critical to defining the channel capacity with the hydraulic model (table 1).

Table 1. Estimated water-surface elevations for a discharge of 500 cubic meters per second; estimated water-surface elevations for discharges of 1,000 and 2,400 cubic meters per second assuming that existing levees and channel banks are raised to confine the flows; and bank or levee elevations along Río Chamelecón at La Lima, Honduras

[**Cross-section stationing**: distance upstream from an arbitrary point near the model boundary; **Minimum channel elevation**, **Water-surface elevation**: elevations are referenced to the World Geodetic System Datum of 1984; **Abbreviations**: km, kilometers; m, meters; m^3/s, cubic meters per second, m/s, meters per second]

Cross section stationing (km)	Minimum channel elevation (m)	Average velocity (m/s) (500 m^3/s)	Elevation, in meters				
			Water-surface (500 m^3/s)	Water-surface (1,000 m^3/s)	Water-surface (2,400 m^3/s)	Top of left bank or levee	Top of right bank or levee
16.276	27.51	0.41	33.75	35.07	38.72	35.03	35.50
15.943	27.50	1.25	33.58	34.76	38.47	33.73	34.80
15.272	26.86	1.43	33.33	34.26	38.09	34.60	35.19
14.984	26.90	1.07	33.20	34.05	38.16	34.40	35.00
13.536	26.10	0.60	32.64	33.64	38.16	32.80	33.50
13.123	25.98	3.42	31.48	33.39	38.15	32.90	34.30
12.681	25.67	1.53	31.08	33.28	38.14	32.00	33.58
12.290	25.41	0.50	30.99	33.26	38.12	31.50	33.70
11.433	24.97	0.61	30.79	33.19	38.09	32.00	36.00
10.765	24.41	1.03	30.46	33.11	38.06	32.00	32.00
10.002	24.04	1.19	30.25	32.91	37.76	31.96	36.00
9.063	23.65	1.76	29.88	32.47	37.13	31.40	31.00
8.513	23.58	1.75	29.61	32.26	36.96	32.18	29.80
8.419	22.12	1.34	29.62	32.27	36.99	31.10	31.60
8.417 (Highway Bridge)							
8.388	23.47	1.73	29.53	31.99	36.75	33.90	32.50
8.276	22.96	0.93	29.57	32.09	36.92	31.75	30.87
8.030	22.86	0.86	29.49	32.07	36.94	31.27	30.40
6.795	22.09	1.53	29.12	31.65	36.24	29.60	29.52
6.540	22.30	1.51	28.97	31.53	36.16	29.50	30.24
6.538 (Foot Bridge)							
6.532	22.30	1.52	28.95	31.44	36.09	29.50	30.24
6.508	22.37	1.34	29.00	31.50	36.19	29.06	30.00
6.506 (Road Bridge)							
6.491	22.37	1.44	28.97	31.44	36.04	29.06	30.00
6.440	22.10	1.84	28.81	31.22	35.67	29.00	30.00
5.942	21.86	1.49	28.65	31.09	35.59	29.40	29.04
5.632	21.79	1.54	28.55	30.96	35.39	28.90	28.84
5.481	21.82	1.84	28.45	30.78	35.03	29.70	30.07
5.381	21.48	1.81	28.37	30.69	35.01	29.40	31.30
4.953	20.97	1.42	28.27	30.59	34.90	29.50	31.45
4.317	20.86	2.19	27.85	30.05	34.26	29.00	28.60
3.970	20.59	1.72	27.71	29.90	34.15	28.90	29.76
3.149	20.07	1.62	27.37	29.54	33.75	29.70	27.69
2.701	20.21	2.84	26.66	28.84	33.07	28.80	30.05
2.337	19.76	1.91	26.44	28.70	33.08	29.00	28.00
2.030	20.16	2.99	25.73	28.16	32.70	28.38	28.20
1.689	19.71	1.76	25.68	28.09	32.62	28.00	27.70
0.496	19.42	1.46	25.22	27.67	32.30	27.00	28.78
0.160	18.38	1.90	24.98	27.37	31.83	26.40	28.90

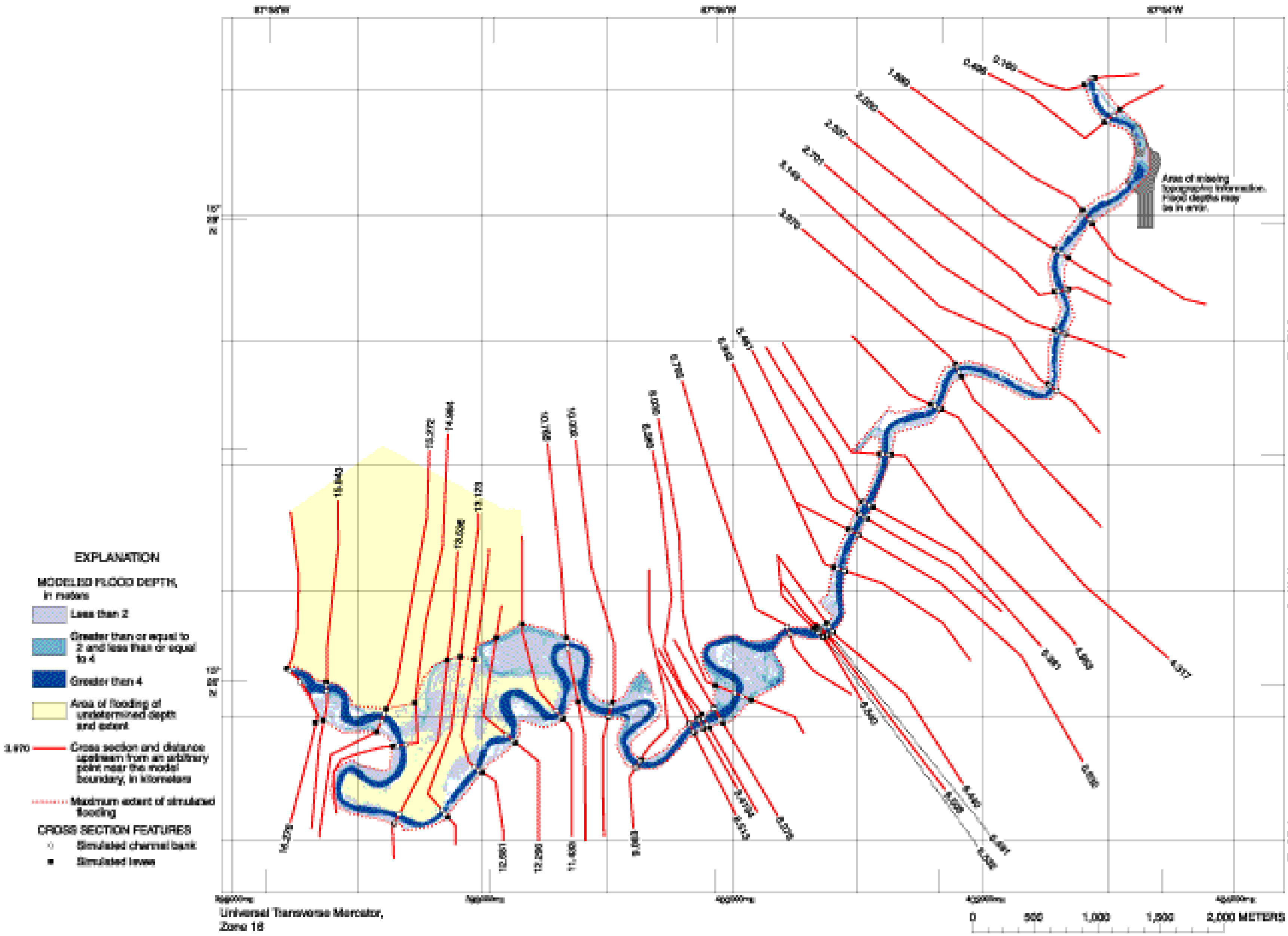

Figure 2. Depth of inundation of a discharge of 500 cubic feet per second, extent of simulated flooding, and location of cross sections on Río Chamelecón at La Lima, Honduras.

Most hydraulic calculations of flow in channels and overbank areas require an estimate of flow resistance, which is generally expressed as Manning's roughness coefficient, *n*. The effect that roughness coefficients have on water-surface profiles is that as the *n* value is increased, the resistance to flow increases also, which results in higher water-surface profiles. Roughness coefficients (Manning's *n*) for Río Chamelecón were estimated from field observations and digital photographs taken during the ground surveys of the three bridges on March 21, 2000, and January 13, 2001, and from computer displays of shaded-relief images of the LIDAR-derived DEM before the vegetation removal filter was applied. The *n* values estimated for the main channel of Río Chamelecón was 0.034, and the *n* values estimated for the overbank areas ranged from 0.070 to 0.090. The higher *n* values were applied to areas of dense urban areas or heavy crops.

Step-backwater computations require a water-surface elevation as a boundary condition at either the downstream end of the stream reach for flows in the subcritical flow regime or at the upstream end of the reach for flows in the supercritical flow regime. Initial HEC-RAS simulations indicated that the flow in Río Chamelecón would be in the subcritical flow regime; therefore, the boundary condition used was a water-surface elevation at cross section 0.160, the farthest downstream cross section in the Río Chamelecón step-backwater model. An elevation of 24.98 meters was estimated by a slope-conveyance computation assuming an energy gradient of 0.0006, which was estimated to be equal to the slope of the main channel bed. The computed water-surface elevations at the first few cross sections upstream may differ from the true elevations if the estimated boundary condition elevation is incorrect. However, if the error in the estimated boundary condition is not large, the computed profile asymptotically approaches the true profile within a few cross sections.

La Lima begins to have flooding problems when the discharge in Río Chamelecón rises to 500 m^3/s (Humberto Calderon, Comision Ejecutiva Valle de Sula, oral commun., March 2000). Trial-and-error runs of the hydraulic model with various discharges showed that this is a good estimate of the channel capacity of the main channel through the urban area of La Lima. At this discharge, the water-surface elevation was estimated to be within 0.1 meter of the top of the sandbag levee observed on the left bank at the two bridges in town and about 1 meter below the top of the vertical wall on the right bank. At the downstream side of the highway bridge, the field-surveyed elevations of the top of the levee are 2.4 meters above the estimated water-surface elevation on the left bank and 0.7 meter above the estimated water-surface elevation on the right bank. Upstream of cross section 10.765 on the left bank, no well-defined levee could be detected in the LIDAR images of the floodplain until cross section 16.276, the most upstream cross section. Simulated overbank flow between cross sections 10.765 and 15.272 was constrained in the numerical model by placing fictitious levees on the bank away from the channel at slightly higher ground, just beyond what appears to be meander scars from previous channel locations. The left-bank elevation at cross section 15.943 is only 0.15 meter above the estimated water-surface elevation of the 500 m^3/s discharge, and just upstream and downstream of the cross section the bank elevation is lower than the estimated water-surface elevation. Shallow flooding of an undetermined amount is expected to spill over the left bank in this region and inundate the area, and would most likely drain to the north and east in the several ditches located in the area.

The Río Chamelecón step-backwater model provided estimates of water-surface elevations and average velocities at all cross sections for a discharge of 500 m^3/s (table 1 and figure 3). After the main channel capacity was determined at 500 m^3/s, the existing top of levees and channel banks were raised 10 meters in the numerical model to constrain the extent of flooding for higher flows to the main channel.

The model was rerun with discharges of 1,000 and 2,400 m^3/s. These discharge values represent the approximate capacity of the bridges and the 50-year flood, respectively. The water-surface elevations for these higher discharges are shown in table 1 and figure 3. The difference between these water-surface elevations and the elevations of the top of levee or channel bank represents the minimum height that the existing levees need to be raised in order to constrain these floods to the main channel. These differences for the 1,000 m^3/s flood average 0.89 meter for the left bank and 0.30 meter for the right bank, with a maximum difference between the water surface and the top of levee of 2.46 meters. The water-surface elevations for the 1,000 m^3/s flood are estimated to be just above the low-chord elevations on all three of the bridges, but below the elevation of the bridge deck.

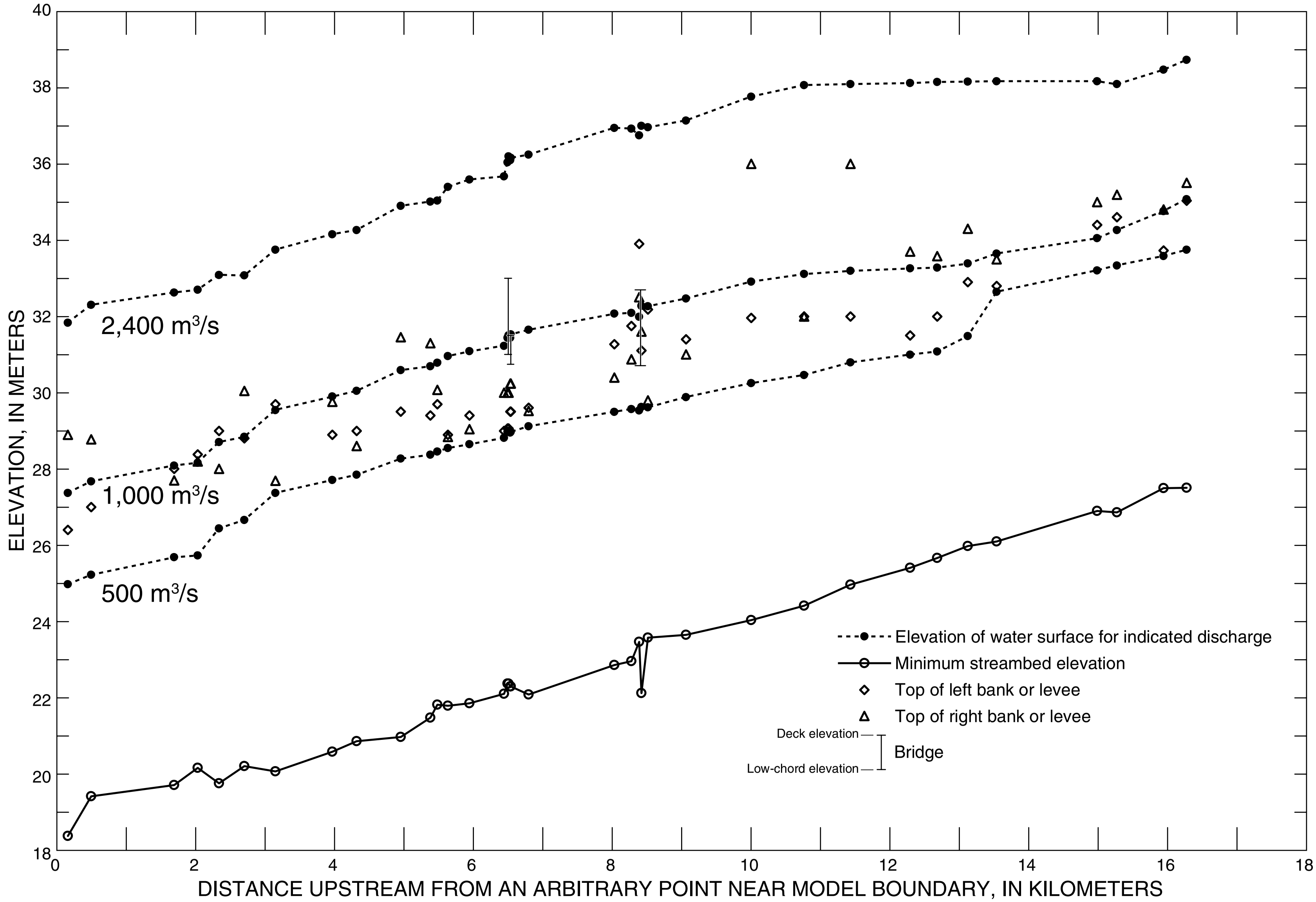

Figure 3. Water-surface profiles, estimated using the step-backwater model HEC-RAS, for discharges of 500, 1,000, and 2,400 cubic meters per second (m^3/s) confined within the main channel and levee or bank elevations on Río Chamelecón at La Lima, Honduras.

When the water-surface elevations are in contact with the bridge, slight changes in flow or blockages of the bridge opening can cause dramatic changes in the water-surface elevations. Therefore, the 1,000 m^3/s flood, which is estimated to be in contact with the bridge is slightly above what should be considered a safe flow capacity for these bridges. The differences between the water-surface elevations for the 2,400 m^3/s flood and the elevations of the top of levee or channel bank average 5.39 meters for the left bank and 4.80 meters for the right bank, with a maximum difference of 7.16 meters.

FLOOD-INUNDATION MAPS

The results from the step-backwater hydraulic model were processed by the computer program HEC-GeoRAS to create GIS coverages of the area and depth of inundation for the study area. The GIS coverage of area of inundation was created by intersecting the computed water-surface elevations with the topographic TIN that was produced from the LIDAR data. This coverage was then overlain on an existing 1:50,000 topographic digital raster graphics map (figure 1) produced by the National Imagery and Mapping Agency (Gary Fairgrieve, USGS, written commun., 1999). Depth of inundation for a 500 m^3/s discharge (figure 2) was computed by subtracting the topographic TIN from a computed water-surface elevation TIN to produce a grid with a cell size of 2.5 meters.

The maximum extent of the flooding for a discharge of 500 m^3/s was constrained to a boundary delineated along the top of existing levees or channel banks that coincided with the placement of levees in the numerical model (figure 2). However, on the left bank of the river in the upper reach of the model, some water of an undetermined amount is expected to overflow the channel banks and flow northward beyond the flood boundary. The northern extent of this area of shallow flooding (figure 1 and 2) is not known, but a boundary was placed along an existing drainage canal and extended to the left-bank end of cross section 16.276. Some shallow flooding may extend beyond this boundary.

The blue lines depicting the Río Choloma channel on the digital raster graphics map used as the base map for figure 1 lies outside the 500-m^3/s discharge boundaries at some locations. This probably results from changes in the river course as a result of flood flows that occurred after the map was created, especially those that resulted from Hurricane Mitch.

The flood-hazard maps are intended to provide a basic tool for planning or for engineering projects in or near the Río Chamelecón floodplain. This tool can reasonably separate high-hazard from low-hazard areas in the floodplain, to minimize future flooding losses. However, significant introduced or natural changes in main-channel or floodplain geometry or location can affect the area and depth of inundation. Also, encroachment into the floodplain with structures or fill will reduce the flood-carrying capacity of the channel and thereby increase the potential height of floodwaters, and may also alter the area of inundation. Natural filling and scouring of the channel can also affect flood elevation and areas inundated.

DATA AVAILABILITY

GIS coverages of flood inundation and flood depths shown on the maps in figures 1 and 2 are available in the Municipal GIS project, a concurrent USAID-sponsored USGS project that will integrate maps, orthorectified aerial photography, and other available natural resource data for a particular municipality into a common geographic database. The GIS project, which is located on a computer in the La Lima municipality office, allows users to view the GIS coverages in much more detail than shown on figures 1 and 2. The GIS project will also allow users to overlay other GIS coverages over the inundation and flood-depth boundaries to further facilitate planning and engineering. Additional information about the Municipal GIS project is available on the Internet at the GIS Products Web page (http://mitchnts1.cr.usgs.gov/projects/gis.html), a part of the USGS Hurricane Mitch Program Web site.

The GIS coverages and the HEC-RAS model files for this study are available on the Internet at the Flood Hazard Mapping Web page (http://mitchnts1.cr.usgs.gov/projects/floodhazard.html), which is also a part of the USGS Hurricane Mitch Program Web site.

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